THE MASONRY CENTRE

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UNIVERSITY OF ALBERTA
Department of Civil & Environmental Engineering

LOCATION
Innovation Centre for Engineering (ICE), pictured
9211-116 Street
Edmonton, AB T6G 1H9

CONTACT
Carlos Cruz-Noguez, PhD, PEng
(780) 492-2794
cruznogu@ualberta.ca
www.ccruzn.com

INSIDE THIS ISSUE

The Masonry Centre develops state-of-the art masonry systems that are economic, durable, and sustainable solutions in response to the challenges brought by climate change and energy scarcity. Our professors have an active voice on the writing of the building and energy codes in North America. Our engineering students go on to shape the future of Canadian infrastructure.

A message from the MCAA Chair

DR. CARLOS A. CRUZ NOGUEZ

Amidst these unprecedented times, our main concern has been the safety of our students, faculty and staff. We have diligently worked to empower our students so that they can safely continue conducting their research from home if they so choose. Together with the other professors in the Structures Group at the UofA we are finding alternatives for those engaged in experimental testing, so we can minimize the impact to their research programs. The health and wellbeing of our team is paramount.

The COVID-19 situation has also impacted committee work from some of the members of the centre. The 2020 ACI Convention at Rosemont/Chicago and the 2020 Spring TMS meeting at Charlotte had been cancelled. Committee work is, going ahead in online meetings. Several conferences attended by our students (IMC, CSCE, WCEE) have been impacted as well.

Despite the constraints, our team is making strides and we are glad to see our group maturing. The Centre's personnel are working on exciting projects on masonry simulation and reliability, composite behaviour, thermal performance, and large-scale testing of slender masonry walls — more details in the newsletter. Our valued contractor partner, the Masonry Contractor Association of Alberta – Northern Chapter, has continued to show us unwavering technical, material, and moral support.

In another front, The Masonry Centre joined the Canada-US task force that is looking to harmonize the codes in the two countries. The team includes one of our PhD students (C. Pettit). Two masonry building archetypes (a multi-storey building and a warehouse) were designed by the team in cities located next to each other at both sides of the border, using loads and design codes specific from each country. This has led to valuable insight onto the inner workings and underlying philosophies in the CSA S304 and TMS 402, and changes are underway for the next version of S304.

Our commitment to masonry education remains strong. Three graduate scholarships and one at the undergraduate level have been set up to attract and recognize top student talent to the Masonry Centre. Noteworthy among them is the prestigious MCAA-North Graduate Recruitment Scholarship, with a value of $10,000 and offered yearly in open competition to national and international students wishing to pursue an MSc/PhD in Structural Engineering at the UofA, with a focus on structural masonry. The 2019 recipient was M. Ismaiel, a PhD student in the thermal and energy efficiency stream. The 2020 recipient will be announced in September and the selection process is underway.

STRUCTURAL PERFORMANCE AND INNOVATIVE MASONRY COMPONENTS

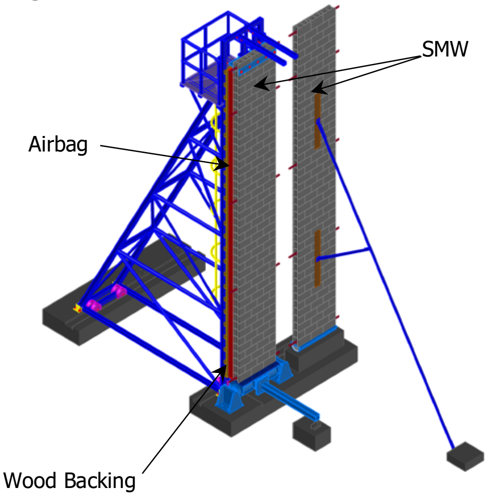
CARLOS A. CRUZ NOGUEZ

PH.D., P.ENG., ASSOCIATE PROFESSOR, MCAA CHAIR OF MASONRY STRUCTURES

MODERNIZING THE DESIGN CODE FOR SLENDER MASONRY WALLS (SMW)

RIVERS AA, GONZALEZ R, BILOTTA M, PETTIT C, TOMLINSON D, CRUZ NOGUEZ C

Since 1980 there has been no innovation to the design of SMWs despite many improvements in masonry material properties, construction methods, and inspection levels. Dr. Cruz's team is using a macro-modelling approach to obtain a more appropriate understanding of contemporary SMWs, which can be used to improve the existing design methods. Following a pre-analysis study on a wide range of slenderness ratios, reinforcement placement and realistic fixity conditions at the base, a design for full-scale specimens was made for use in the next phase of this research (shown below). This full-scale model will be used to study conventional, in-line cage, and near-surface mounted reinforcements to determine new economical designs that maintain structural strength and performance. In addition, another study is being done to determine the appropriate modifications to CSA S304-14 and TMS 402/602-16 that would ease the limitations on SMW posed by these codes.

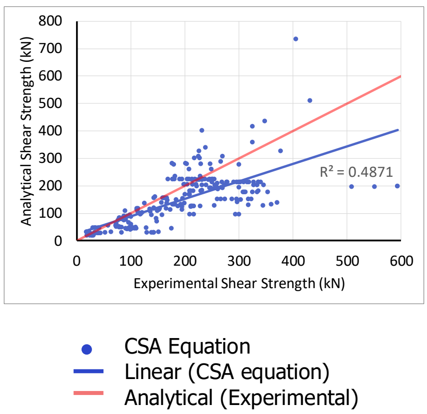


DESIGN OF FULL-SCALE MODEL FOR TESTING SMW

INCREASING THE ACCURACY OF SHEAR STRENGTH PREDICTIONS FOR PARTIALLY GROUTED MASONRY WALLS

DUQUE K, CRUZ C

There is currently a high degree of variance in the in-plane shear strength results with the current design code equations (e.g. CSA equation, shown below). The predicted strength values can be either over-conservative or unconservative; such variability can lead to designs that are both uneconomical and unsafe. As an alternative expression for predicting the in-plane shear strength of partially grouted masonry walls, stepwise regression and model trees were used. Several models were developed and validated using statistical analysis and reserved data. When tested using statistically significant variables, these models performed well in capturing the shear behaviour of partially grouted walls. These preliminary models indicate that stepwise regression and model trees could be used to generate a new equation with better accuracy than the current CSA equation. Furthermore, these new equations maintain the appropriate level of simplicity such that they could feasibly be adopted into a design code.



PERFORMANCE OF CSA SHEAR STRENGTH EQUATION FOR MASONRY WALLS

ENERGY EFFICIENCY AND ADVANCED THERMAL MODELLING OF MASONRY WALLS

YUXIANG CHEN

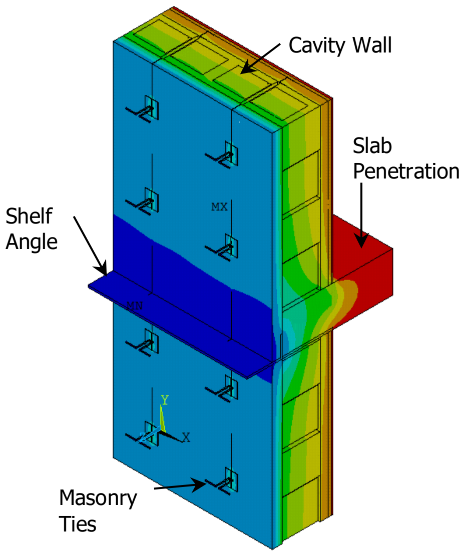
PH.D., P.ENG., ASSISTANT PROFESSOR

IMPROVING THERMAL RESISTANCE OF MASONRY EXTERIOR WALLS

ISMAIEL M, HUYNH A, SHAO Y, CHEN Y

Increasing the thermal resistance of masonry exterior walls can reduce a building's energy consumption. Dr. Chen's team is studying, theoretically and experimentally, the overall thermal behaviour of masonry walls including all its components: air gaps, ties, and shelf angles. The group aims to develop a method for obtaining reliable energy-estimation needs for the buildings without any complicated computer simulations.

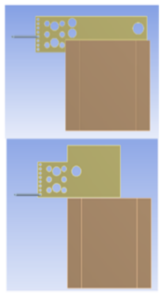
Finite element modelling is used to accurately analyse the thermal behaviour of each element; specific focus is given on shelf angles and wall ties.



THERMAL DISTRIBUTION OF A CAVITY WALL WITH SHELF ANGLES, MASONRY TIES AND SLAB PENETRATION

Shelf Angles: Traditional shelf angle design (direct anchoring to the structural backup) interrupts the continuity of the insulation, thus significantly reducing its effectiveness. Studies are being done to understand the effect of offsetting shelf angles to improve continuous insulation.

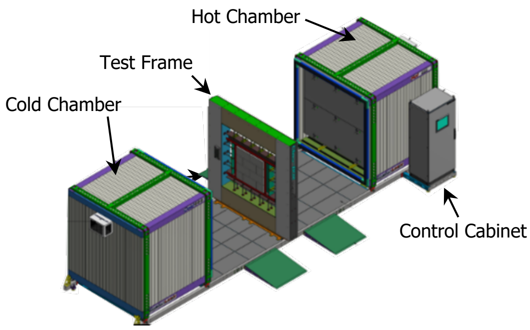
Masonry Ties: Masonry wall ties are one of the main thermal bridging sources in masonry exterior walls. They cause a significant reduction in the thermal resistance of the walls. A solution is needed to reduce the effect of the masonry ties on the thermal performance of exterior masonry walls. Different tie spacing, shapes and dimensions on the overall thermal resistance of masonry walls were compared. One of the results indicates that reducing the thermal contact at the interior ends of the ties can significantly reduce the thermal bridging impact (shown below).



REDUCED THERMAL BRIDGING WITH REDUCED THERMAL CONTACT

Environmental chamber experiment:

The Centre is in the process of acquiring a state-of-the-art environmental chamber that will be used to test the thermal performance of different wall configurations and components (e.g. the effective thermal resistance, R). The measured R-values will be used to validate and improve the modeling approaches and to verify and improve the future designs of masonry walls and its components.



MECHANICAL AND PROBABLISTIC MODELLING FOR MASONRY WALLS

YONG LI

PH.D., ASSISTANT PROFESSOR

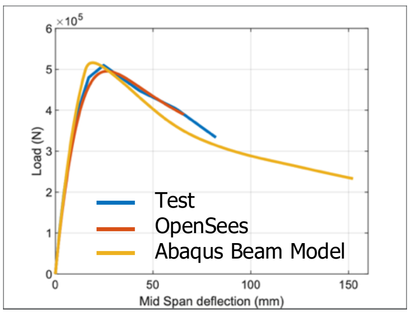
MACRO-MODELLING APPROACH TO STUDY THE OUT-OF-PLANE BEHAVIOUR OF REINFORCED CONCRETE MASONRY WALLS

METWALLY Z, LI Y

By using a combination of mechanics-based finite element modelling, current predictive capacity models, and available experimental data, the Li group is examining the out-of-plane behaviour of reinforced concrete masonry walls. This approach has been used to capture the global behaviour and the elastic behaviour, ultimate capacity, and post-peak behaviours (shown below) for different boundary and loading conditions.

There is a large variance in performance test of masonry walls, which leads to the conservative design codes. The current code-based design depends on the understanding of the probabilistic behaviour of masonry walls while accounting for important uncertainties. Quantifying these uncertainties is necessary for the development of more reliable models for the purposes of structural design and performance evaluation of masonry walls.

As part of the research goal, Li's group is also evaluating probabilistically the different design and modelling approaches, in particular the CSA recommend design code model — the moment magnifier method.



GLOBAL BEHAVIOUR OF A WALL CAPTURED BY DIFFERENT MACRO-MODELLING FEM APPROACHES USING TWO PROPRIETARY SOFTWARE TOOLS: *OPENSEES* (UC BERKELEY) AND *ABAQUS* (MIT)

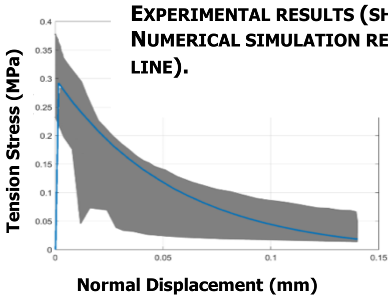
MICRO-MODELLING OF FAILURES AND GLOBAL SENSITIVITY IN MASONRY WALLS BASED ON FEM

ZENG B, LI Y

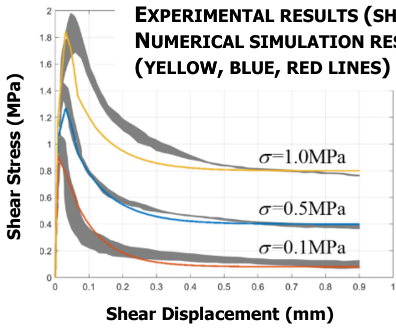
Masonry walls can be subjected to complex stress states that could result in various failure modes. Gaining further understanding of these mechanisms can lead to more reliable masonry walls designs.

Finite element models were used to study different failure modes (e.g. tension cracking, compressive crushing, and shear sliding in joints) in masonry structures. The mechanical property parameters of each component (mortar, joints, unit blocks) were individually calibrated form existing experimental results, but subject to large variations. Graphs below, are the results of a study on joints under tension (top) and shear (bottom). The variations in the structural behavior due to uncertainties in masonry walls are studied through global sensitivity analysis.

TENSION BEHAVIOR OF MORTAR JOINTS. EXPERIMENTAL RESULTS (SHADED AREA); NUMERICAL SIMULATION RESULTS (BLUE LINE).



SHEAR BEHAVIOUR OF MORTAR JOINTS. EXPERIMENTAL RESULTS (SHADED AREA) NUMERICAL SIMULATION RESULTS (YELLOW, BLUE, RED LINES)



BEHAVIOUR OF PARTIALLY COMPOSITE SYSTEMS AND CONNECTIONS UNDER STRUCTURAL LOADING

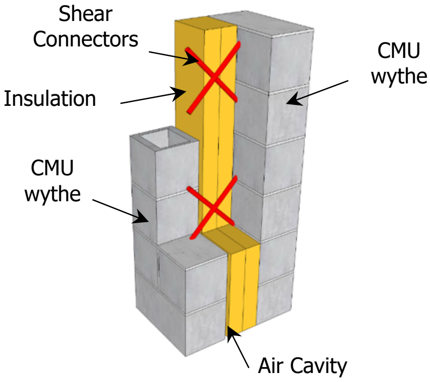
DOUG TOMLINSON

PH.D., ASSISTANT PROFESSOR

DESIGNING COST-EFFECTIVE DOUBLE-WYTHE WALLS

EGBON B, TOMLINSON D

There is an absence of substantial test data regarding the performance of double-wythe masonry wallets joined with shear connectors relative to other systems (e.g. concrete insulated wall panels). The Tomlinson lab is developing structural design guidelines for walls, accounting for composite action provided by both commonly used and novel shear connectors in double-wythe masonry walls. Inclined connectors are stronger and stiffer than the dowel-type connectors commonly used in walls. A study on one novel connector (inclined fibreglass rebar) is underway. A 3-D printed system was developed to help align inclined connectors for fabrication in masonry walls. Direct shear testing was completed on a wall with concrete wythes to refine proposed connector analytical models. Test results are being used to adapt analytical and finite element models previously verified with concrete walls for masonry systems.



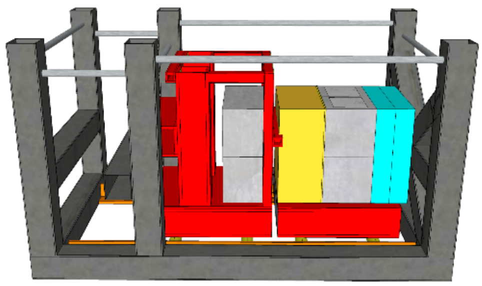
COMPOSITE CAVITY WALL WITH NOVEL CONNECTORS

The revised models combined with the small-scale testing in the following project will be used to design and test full-scale masonry walls in the next phase of this work.

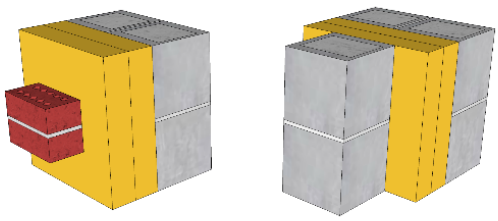
ANALYZING CONNECTOR BEHAVIOUR

ROMERO D, TOMLINSON D

The structural response of shear connectors in masonry walls will be analyzed under tension, compression, and shear using self-reacting frames designed based on previously published methods (1,2). Fabrication of these frames is underway. These load frames will be used to test various mini-wall specimens to evaluate the response of both common and novel connectors. Load and displacement data (using traditional potentiometers as well as Digital Image Correlation (DIC)) will be collected from each mini-wall in order to understand the partially composite behaviour of these masonry wall components. Results from these small-scale studies will be used to refine shear connector structural models for the design of full-scale walls planned for future testing, as well as to compare with thermal resistance work completed by Dr. Chen's lab.



ABOVE: SCHEMATIC OF TENSION/COMPRESSION LOAD FRAME WITH MINI WALL (YELLOW)
BELOW: MINI-WALL SPECIMENS FOR SHEAR TESTS (LEFT) VENEER WALL AND (RIGHT) CAVITY WALL.



(1) ***In-Plane Stiffness and Strength of Adjustable Wall Ties,*** William CR and Hamid AA (2005)
(2) ***Strength and Behaviour of Metal Ties in 2-Wythe Masonry Walls,*** Hatzinikolas M, Longworth 2 and Warwaruk J (1980)

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